

## ASSESSMENT PRINCIPLES OF LAND FRAGMENTATION

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### Abstract

The problem of land fragmentation is analyzed and discussed in various studies from different perspectives. Various authors have used different measures and coefficients to describe the land fragmentation although none of the indicators gives a full assessment of this phenomenon. This is due to the wide range nature of the land fragmentation and different approaches to these problems. The paper describes the various factors of land fragmentation. They are selected to describe its several different parameters.

The economically active farms of Rubene rural municipality by their sizes and the number of land units were chosen as the research object to examine usage of the above parameters for assessment of the fragmentation of the farms.

**Key words** – land parcel, land plot, land fragmentation.

### Introduction

Last Latvian land reform has substantially altered the land usage structure of land properties and farm lands in rural areas. It has resulted in the emergence of many very small agricultural land properties. Their separate land parcels are often located far apart, they are not easily accessible and are situated unsuitably for agricultural purposes. Although the Land Reform legislation initially provided creation of favorable regional preconditions for successful development of agricultural production, suggesting compact farms and avoiding inter-areas (Nolikums par Latvijas...,1991), in the practice, due to different objective and sometimes subjective factors, farm land properties were formed on a number of land parcels, resulting in land fragmentation and inter-areas (Jankava, 2003).

After that, little by little, under more favorable circumstances for agriculture, the land market evolved in the parallel of the processes of land privatization. It has resulted in increasing of the farms sizes through the sale, leases and other transactions. This is demonstrated by the studies of dynamics of land areas of economically active farms (2003 - 2007), derived from the Central Statistical Bureau of the Republic of Latvia (Янкава, Менготс, 2009). The average area of farms by the total area and by the agriculturally usable land and the sown area are increasing over the years.

Although their average area is still very small; besides, a significant proportion of them represents a very small farms. The distribution survey of farm lands of Latvia by the year 2007 showed that almost 80% of their total number and more than 30% of the total area were amounted to a holding area of up to 2 ha (Янкава, Менготс, 2009).

Development of the land market contributes to the fragmentation of holdings because it is not always possible to find an adjacent land plot to buy or lease for the land area building up purpose. Land fragmentation makes farming and land management difficult, it increases also transport costs. Similar processes occur in rural areas of our immediate neighbors - Lithuania (Lankelis, 2002) and Estonia (Maasikamäe, 2005), as well as in other Eastern and Western European countries (Хоржан, 2005).

This phenomenon causes the fact that farmers are feeling difficult to introduce new competitive manufacturing steps and to use the appropriate technique; therefore many farmers are forced to engage the production only for living, unable to participate in the manufacturing for commercial purposes.

While there are a number of information basis in Latvia, like State Real Estate Cadastre Information System (IS RESC), as well as the Central Statistical Bureau, by which aggregated data we may have an overall view on the farms size, fragmentation, number of the land parcels forming a land plot, but each of them also have their weaknesses. By RESC IS data, it is not possible to know the real farms areas because not all rural farmers register lease lands in this information system. The most recent data by the Central Statistical Bureau is only about the year 2007.

These considerations prompted the choice of the subject and *the aim of the research* was set – to explore fragmentation of farm lands and opportunities of applying different its characterizing indicators. The *tasks* were set to reach the aim:

1. to complete theoretical analysis on the land fragmentation and its characterizing indicators;
2. to analyze fragmentation of the land areas of the largest farms of Rubene rural municipality;
3. to observe advantages and disadvantages of the land fragmentation indicators.

Rubene rural municipality of Jekabpils district was chosen as the study site, analyzing the lands fragmentation of economically active farms (*economically active farms*, according to CSB of the Republic of Latvia (Lauku saimniecību struktūra, 2009) are defined as the farms producing agricultural products regardless of production quantity and type of its usage or have maintained good agricultural and environmental conditions in the land).

The study is designed primarily as analysis and comparison of a variety of indicators of land fragmentation in scientific literature that is based on the methods of analysis, synthesis, research of statistical data and graphical representation. Examples of Rubene rural municipality cadastral maps are applied using orthophotos and topographic maps to illustrate and explain the matter of the land fragmentation issue.

Some basic concepts are applied in the work and it is necessary to clarify these concepts to avoid confusion and misunderstanding.

Referring to the Law on Land Survey (*Zemes ierīcības likums*, 2006), *inter-area* is a separately situated land parcel which is separated from the main land parcel by land owned by another person. But the Law does not say what the main land parcel is, therefore it is set in the research that the main land parcel is a land plot with the living and administrative or production centre on it or, if there is not one, one of the land plots.

A land plot is defined by the scientist S.Maasikamāe as follows: *land plot* is a notion used to describe generally a land area regardless its property rights, land using form, etc. A land plot can be a single parcel, a separate (one in total) field or a pasture (a meadow) (Maasikamāe, 2005).

In this article, its authors define a land plot as a compact area that is compound of one or several land parcels not including public roads.

*Land property* – all real estate which property rights are enshrined in the Land Register.

*Land use* is understood as a farm area allocated on the basis of ownership or on lease basis, or as a combination of the both.

## **Results and Discussion**

### **1. Indicators for Land Fragmentation Characterization**

With the land fragmentation, the situation is identified where the land property or farm land use consists of several parcels of land, which are separated by any other property or farm lands. Fragmentation of the land should be understood firstly as a spatial phenomenon and, for substantive understanding, the land fragmentation should be treated as a multilevel phenomenon. The scientist S.Maasikamāe suggests indicating of internal and external land fragmentation, describing the above situation as the external land fragmentation and mutual location of the kinds of land uses within the land parcel as the internal fragmentation (Maasikamāe, 2005).

Spatial characteristics of the land ownership and use (geographical location, land parcels size, shape, etc.) are generally viewed as most of the fragmentation parameters. Land fragmentation indicators are used to specify spatial characteristics of the land properties and use.

Basing on definite research works (Butāne, 1998; Locmers, 1999; Lankelis, 2002; Jankava, 2003; Maasikamāe, Mugu 2003), land fragmentation can be characterized by several indicators:

1. *Number of land parcels* that is usually counted to calculate the average number of land parcels in the farms in the territorial unit. The easiest way to calculate the number of the land parcels per farm land uses, as marked by the scientist S.Maasikamāe (Maasikamāe, 2005), is to distribute the total number of land parcels with the total number of farms. Average number of parcels of the property or land-use does not reflect correctly the actual land use situation and true land fragmentation, if, for instance, there are land parcels divided by a public road (Fig.1.) or simply adjacent ones.

Nature and volume of the problem are illustrated in Figure 1 with an example of Rubene municipality. A farm that consists of three land parcels, according to the cadastral information system data, in this example, is divided by natural and man-made (roads) boundaries. But if this situation were regarded not by the cadastral data, but by the land use from agricultural point of view, then this example reflects a compact territory which is divided by a road or which consists of the land parcels owned (Fig. 1, land parcels 1 and 3) or rented (2) by the farmers. This means that this farm has to be considered as one of the group of properties consisting of a single land parcel.



Source: the authors, by the data of Rubene municipality.

Figure 1. Scheme of Territorial Location of the Farms.

To obtain a more accurate assessment indicators of the situation on the average size or number of farm land parcels, actual placement test (for example, in the map) of the land parcels belonging to single property or managed by a farm is required. The above test results should be taken into account to calculate the correct average.

2. *Form of Territory of a Farm.* Different compactness ratios are usually calculated that are mainly used to specify the land plot form.

The form of a land plot has been a research subject to several Latvian scientists (Лощер, 1980; Butāne, 1998; Butāne, Lasteniece, 1999). The main advantage of the various compactness ratios proposed by the authors is that they give a numerical description of the forms of land plots in accordance with the conditions. The land plot can be a single field, property, rural or other area.

Land form is characterized by *the farm configuration* that can be very different (Fig. 2). By the external configuration of shapes, the farms can be relatively divided in farms of regular geometric shapes (square, rectangular, trapezoidal, etc.), of likely geometric or similar shapes and of irregular forms.



Source: the authors, by the data of Rubene municipality.

Figure 2. Configuration Forms of the Farms.

In the Soviet-era studies, a square farm area with straight lines borders and fences located in the territory of the geometric center was taken as a benchmark. Also in later years of already renewed Republic of Latvia, it was suggested to apply this benchmark for determination of the configuration of farms, especially those with the area exceeding 50 ha (Butāne, Lasteniece, 1999).

Real farms have larger or smaller deviations from the accepted benchmark of the ideal site location (Fig.2). These deviations from the benchmark are commonly described as the failures of the territorial location which make the use of the land, technical and other means of production and efficient use of labor force difficult, increase transportation and other annual costs and reduce competitiveness of the farm.

According to the above authors' recommendations, *the compactness of the farm* has to be understood as spatial configuration and location in relation to fencing and road networks that can be calculated by formula 1.

$$K = \frac{R_1}{0.043\sqrt{P}}, \quad (1)$$

where  $R_1$  – weighted average distance from the fence to the area, km;  
 $P$  – the agriculturally usable land area of the farms, ha.

The closer the coefficients value to 1, the better the compactness of the farm.

*The authors' proposed external farm compactness coefficient* depends on the size, shape, number and territorial distribution of the land plots. The external compactness coefficient of the farm can be calculated by the formula 2; the closer the ratio to 1, the better.

$$K_1 = \frac{R_2}{0.038\sqrt{P}}, \quad (2)$$

where  $R_2$  – the average distance by air line from the geometric center of the farm to the territory, km.

To characterize better the external compactness of the farm, one can calculate the factors of external compactness, outstretch, inter-area and external borders placement.

The external borders placement coefficient expresses the difference between the border length of the concrete farm and the square root of the perimeter of the same area. As the coefficient is closer to 1 as the borders of the farm are less sinuous and hence more advantageous from the configuration standpoint.

$$K_2 = \frac{F}{0.4\sqrt{P_1}}, \quad (3)$$

where  $F$  – length of the external borders, km;  
 $P_1$  – the total area of the farm, ha.

It has to be marked that this coefficient is very similar to the scientist's Burihin compactness coefficient referenced in the article by Professor S. Maasikamae (Maasikamäe, 2005).

The scientists recommended methods and indicators for describing the land forms can be used nowadays, but that is not enough. The main reason is that the land use situation in agriculture is changed today and one agricultural work unit is much more fragmented by the territory in comparison to the past.

3. *The territorial distribution of the land plots owned by the farms* can be characterized by several parameters of fragmentation by indicators of different types.

M. Locmers (Locmers, Saharovs, Stāvausis, 1978), A. Butane and V. Lasteniece (Butāne, Lasteniece, 1999) recommend to use the proportion of inter-areas of the total farm area, distance of the inter-areas to the main land plot and *inter-area coefficient*, calculated by the Formula 4, as the characterizing indicators of the territorial location.

$$K_3 = 1 - \frac{K}{K_0} \quad (4)$$

where  $K$  – compactness coefficient of the farm;  
 $K_0$  – compactness coefficient of the main land plot.

Scientists of the Western countries, like Januszewski, Simmons, have approached to the development of land fragmentation characterization indicators, called indexes, as pointed by the scientist S.Maasikamae (Maasikamäe, 2005).

Januszewski's index application makes it possible to describe the layout of areas of a single property among its land parcels. Januszewski's index is calculated by dividing the square root of the total area of the land property and use by the square root of the sum of the areas of the land parcels (5):

$$K_J = \frac{\sqrt{S}}{\sum \sqrt{S_i}} \quad (5)$$

where  $K_J$  – Januszewski's index of land fragmentation;  
 $S$  – total area of landholding or property;  
 $S_i$  – the area of  $i$ -th parcel.

Januszewski's index is 1 when the land property and use consists of one land parcel and it is less than 1, if the property has more than one land parcel.

The index recommended by Simmons for measuring of the fragmentation of land, is quite similar in nature to the Januszewski's index. The fragmentation index can be calculated by formula as follows (6):

$$K_S = \frac{\sum S_i^2}{S^2} \quad (6)$$

where  $K_S$  – Simmons's index of land fragmentation;  
 $S$  – total area of landholding or property;  
 $S_i$  – the area of  $i$ -th parcel.

Simmons's index value is 1 if the property consists of one land parcel and reduces if the number of parcels per property is increasing.

The scientist S. Maasikamäe (Maasikamäe, 2005) evaluating the territorial distribution of land parcels acknowledges that Januszewski's and Simmons's index's benefit is theoretically that they are easy to calculate. This task can be completed on the basis of the data table, just if there are sizes of land parcels owned by a single property. There is no need for measurements on a map. The advantage of these indices is that they include both land parcels and proportions of areas of separate land parcels. It is recommended to consider adjacent land parcels as one. It means that it is necessary to use a map to get more precise data on territorial location of land plots of a single land use.

The disadvantage of these indices is that they do not deal with the forms, sizes and distances of separate land plots because the distance from the farm house to the other land plots is of crucial importance.

Calculation of land fragmentation indices for characterization of territorial location of the land plots is a little bit more complicated because measurements on map are required.

Observing research works by several authors it has to be assumed that different indices point to different kinds of land fragmentation and none of the indices describes all the parameters because every index of land fragmentation has its advantages and disadvantages. Joint application of different indices provides more information on the land use situation and stresses that different indices are connected. The analyses of land fragmentation should point to the land use opportunities and situation. Therefore the article further deals with the analyses on land fragmentation of farms of Rubene rural area of Jekabpils district by the structure of their land properties and uses.

## 2. Analyses of Farms Fragmentation at Rubene Rural Municipality

Rubene rural municipality is situated at the South of Jekabpils district. It is the biggest rural municipality of the district by its area. The most part of Rubene rural municipality (45%) consists of agriculturally usable land. Nineteen biggest farms (more than 50 ha totally) performing agricultural production actively were chosen for analyses. The total area of the farms is 2275.01, e.i. 13% of the total area of the rural municipality and 28% of its total agriculturally usable lands (AUL).

Summarizing the data of these farms (Table 1) it can be seen that areas of the farms are 50.90 ha to 278.94 ha and their average area is 119.74 ha. The owned and used land areas are situated on several land parcels, for instance, one of the biggest farms (No.15) consists of 20 land parcels with their average area 10.07 ha. Smaller farms (No.3) are very fragmented as well, located on up to 15 land parcels but there are less land plots – 10 more inter-areas besides the main land plot.

Table 1  
Characterising Indices of Land Fragmentation of Farms of Rubene Rural Municipality on 01.01.2009.

No. of farm	Total area, ha	AUL area, ha	Number of land parcel	Number of land plots	Average weighted distance, km		The coefficient of the compactness ( $K$ )	External compactness coefficient ( $K_1$ )	Coefficient of external borders situation ( $K_2$ )	Coefficient of inter-areas ( $K_3$ )	Januszewski's index of land fragmentation ( $K_4$ )	Simmons's index of land fragmentation ( $K_5$ )
					Along the road	Along the air line						
1	50.90	39.40	4	3	3.66	2.45	13.56	10.26	1.56	-	0.44	0.79
2	51.45	47.75	12	8	0.94	0.67	3.15	2.56	2.35	-1.23	0.35	0.23
3	57.90	38.90	15	11	2.04	1.21	7.60	5.10	1.97	-	0.32	0.15
4	58.40	48.20	6	5	9.62	6.12	32.24	23.19	2.95	-11.40	0.52	0.30
5	70.92	63.15	11	10	3.00	2.06	8.78	6.81	3.34	-2.46	0.37	0.19
6	73.40	52.20	2	1	1.09	0.72	3.51	2.62	1.09	-	1.00	1.00
7	73.60	51.16	4	2	1.24	0.67	4.02	2.47	2.37	-0.63	0.58	0.41
8	86.90	46.40	8	6	2.79	1.89	9.54	7.31	3.08	-2.39	0.51	0.37
9	94.90	68.90	13	9	1.63	1.16	4.56	3.68	3.04	-2.65	0.43	0.45
10	108.60	83.80	10	8	4.83	2.97	13.61	9.48	2.94	-7.85	0.35	0.13
11	123.30	88.90	5	3	13.67	7.70	34.72	22.13	1.90	-28.98	0.48	0.32
12	127.10	97.80	10	5	3.07	1.97	7.56	5.49	3.14	-4.12	0.35	0.15
13	144.10	134.00	18	14	7.11	4.39	16.93	11.83	4.71	-8.29	0.34	0.21
14	151.30	87.04	12	6	5.00	3.19	10.04	7.26	2.99	-3.66	0.31	0.14
15	155.98	68.20	20	16	3.42	2.37	8.53	6.67	4.97	-5.33	0.27	0.16
16	188.00	154.50	6	3	2.36	1.37	4.41	2.90	2.76	-1.15	0.42	0.21
17	188.60	151.00	6	4	2.32	1.29	4.40	2.75	2.74	-1.48	0.45	0.36
18	190.72	140.08	14	12	5.73	3.29	11.26	7.32	3.92	-7.66	0.35	0.23
19	278.94	268.43	6	3	1.22	0.86	1.73	1.38	2.14	-0.32	0.45	0.26

Source: by the authors

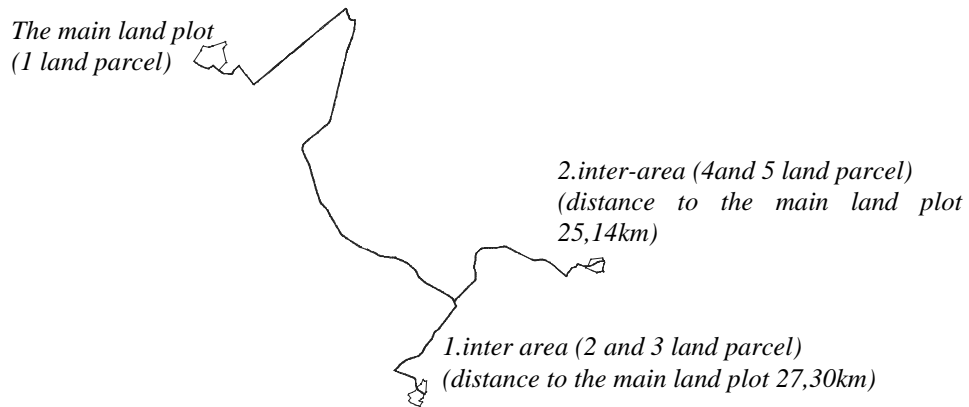
As it was cleared above, the number of the land parcels does not reflect the real land use situation in the farms. Because of this, information was gathered on number of land parcels and inter-areas per a farm. The results (Table 1) show that just one farm (No. 6) does not have inter-areas.

Analyzing the number of land parcels and inter-areas, the above fragmentation characterizing indices were determined (Table 1).

The compactness coefficients of the farms ( $K$ ) are in the range 1.73 – 34.72. It was stated previously that it was desirable that this coefficient would be as close as possible to one. The Table 1 says that the coefficient is even above 10.0 to seven farms. The farm No.11 has the worst compactness coefficient because the areas of the land parcels of the farm are not large and they are situated widely apart (Fig. 4), the weighted average distance from the centre of the main land plot to the inter-areas is 13.67 km.

Analysing the results on the coefficient of the external borders situation ( $K_2$ ) it can be seen (Table 1) that it is in range 1.09 – 4.97, that can be explained with the fact that these farms have the largest numbers of inter-areas that gives the longest border if compared to other farms with less number of inter-areas.

Discussing the territorial location (Figure 3) of the farm (No. 11), it occurs that the farm consists of five land parcels. It could be considered that it as if has four inter-areas but, as it was cleared above, the number of land parcels not always is the same as the number of inter-areas. So the farm No. 11 has just two inter-areas in this situation.



Source: by the authors after the data of Rubene rural municipality.

Figure 3. Scheme of Territorial Location of the Farm No.11

The coefficients of the inter-areas of the farms ( $K_3$ ) are in range from -0.32 to -28.98 but the result with the minus sign is not always easy to characterize. The farm No. 11 has the biggest coefficient of the inter-areas ( $K_3$ ). It has also the largest compactness coefficient ( $K$ ). It proves that these coefficients are interactive. It is impossible to calculate coefficients of the inter-areas ( $K_3$ ) to the farms No.1 and No.3 because there is no agriculturally usable land. One of the farms (No.6), as said above (Table 1), does not have inter-areas, therefore the coefficient of the inter-areas ( $K_3$ ) was not calculated.

Analizing usage of the land fragmentation index by the formulas by Januszewski ( $K_J$ ) and Simmon ( $K_S$ ) it can be seen (Table 1) that they can be calculated also to the farms without agriculturally usable lands within their main land plots, although their indices values differ. By the index of Januszewski ( $K_J$ ), the farm No. 15 is the most fragmented one (the largest number of inter-areas). But by the Simmon's ( $K_S$ ) index, the farm No. 10 is the most fragmented one.

### Conclusions

1. It is advisable to use different indicators for the characterization of the land fragmentation, taking into consideration their different meanings for the description of the fragmentation, it is suggested also to use spatial and cadastre data.
2. The 19 biggest farms of Rubene rural municipality are not compact – their compactness coefficients ( $K$ ) are in range 1.73 – 34.72, their land plots are far apart and this coefficient not always characterizes the true state of the land fragmentation.
3. One of the weaknesses of the largest farms of Rubene rural municipality is inter-areas – the coefficients of the inter-areas ( $K_3$ ) ranging from -0.32 to -28.98, seven farms have more than 6 inter-areas and average area of the inter-areas is beneath 10.0 ha to 3 farms.
4. Taking into account the previous tendencies and research results, as well as the study outcomes at Rubene rural municipality, it would be important further to find the most suitable and efficient methods for the research of the different parameters of the land fragmentation.

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### **Краткое содержание:**

#### **Принципы оценки раздробленности земель**

Проблема раздробленности (фрагментации) земель в различных исследованиях анализирована и рассмотрена в разных аспектах. Многие авторы для характеристики раздробленности земель использовали различные показатели и коэффициенты, хотя не один из них не даёт полной оценки этого явления. Причиной этому является характер широкого спектра раздробленности земель и различный подход к решению этой проблемы

В статье показаны разные коэффициенты фрагментации земель. Они выбраны с целью характеристики различных параметров раздробленности земель.

Чтобы оценить применение этих параметров в характеристике раздробленности земель сельских хозяйств, объектом исследования были выбраны экономически активные сельские хозяйства Рубенской волости по их величине и числу земельных единиц.

**Ключевые слова** - земельная единица, земельный участок, фрагментация земель.

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